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Effect of the osmotic and adiabatic dehydration process on the nutritional composition of tomatoes

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Abstract

The tomato is a horticultural product of commercial importance in Brazil. The Sweet Grape, a hybrid of mini-tomato with a sweeter taste, can be consumed as a side dish, appetizer, or *in natura*. The main commercialization difficulties are related to the post-harvest losses. For being highly perishable, the dehydration process is a great alternative; however, less has been studied about the processing of the hybrid variety Sweet Grape. Therefore, this study aimed at studying the drying technique in two tomato varieties, Italian and Sweet Grape, by analyses of chemical and mineral composition and antioxidants (phenolics, lutein, beta-carotene, lycopene, and ascorbic acid), the tomatoes *in natura,* and the dehydrated products. In general, the processing performed in the Sweet Grape tomatoes preserved the parameters better, compared with the Italian tomatoes. The results allow the conclusion that dehydration maintained the nutritional quality when performed in the Sweet Grape tomatoes.

Keywords: Sweet Grape tomato; dehydration; carotenoids; lycopene; high-performance liquid chromatography.

Practical Application: nutritional composition of dehydrated tomatoes.

1 INTRODUCTION

Cherry-type tomato is considered an exotic vegetable that is used in restaurant menus due to its small size and delicate nature, which adds new flavors and ornaments to the dishes and appetizers, with the advantage of having a reduced size and avoiding waste (Machado et al., 2003). Among the types of cherry tomatoes recently launched on the market, round-shaped or grape-type tomatoes excel, highlighted by the intense red color or yellow in some hybrids, high firmness, resistance to disease, and nutritional value compared with other cultivars (Junqueira et al., 2011; Souza, 2007). One of the hybrids that have been most highlighted is the Sweet Grape tomato, which is smaller and tastier and has been attracting the consumer market.

The tomato is an excellent source of numerous compounds with antioxidant capacity, the main classes of which are carotenoids (lycopene and β-carotene), flavonoid compounds (quercetin, kaempferol, rutin, myricetin, and naringenin), as well as phenolic acids (gallic acid and chlorogenic acid) and vitamin C (Hallmann, 2012).

Carotenoids are substances produced by fruits and vegetables that give them red and orange tones. Currently, more than 600 of these compounds have been described in nature (Almeida-Muradian & Penteado, 2003). Most of the carotenoids present a linear structure with 40 carbons with 3–15 conjugated double bonds, which give them the property of absorbing light in the wavelengths between 400 and 500 nm (Carvalho, 2007). They are also bioactive substances, with beneficial effects on health, and some of them present pro-vitamin A activity (Rodriguez-Amaya et al., 2008). Additionally, they act as photoprotectors in photosynthesis and as membrane stabilizers (Kurz et al., 2008).

Lycopene, an acyclic carotenoid, is completely insoluble in water and slightly soluble in vegetable oil (Mayer-Miebach et al., 2005) and composed of 11 conjugated bonds and 2 unconjugated double bonds (Stahl & Sies, 1996). The main lycopene sources are guava, watermelon, tomatoes, and derived products, such as ketchup, tomato juice, and tomato sauce, among others. Lycopene has a higher absorption after cooking, mainly when prepared in oily media such as tomato sauce (Santos et al., 2003). It is an effective antioxidant compound, which is considered the carotenoid with the highest sequestering ability of singlet oxygen (Arruda et al., 2005; Friedman, 2002; Giovannucci et al., 2002; Markovic et al., 2006; Moritz & Tramonte, 2006).

The industrial processing of tomatoes into tomato-based products includes many thermal treatment steps, such as drying, heating, and pasteurization. These treatments have the purpose of inactivating microorganisms or enzymes, reducing the moisture content, and concentrating the product, always with the intent of increasing the product's lifespan. Throughout the thermal treatments, several additional changes may occur and affect the appearance, composition, nutritional value, and sensory properties in terms of color, texture, and flavor of the product (Capanoglu et al., 2008). However, the transformed tomatoes might have a lower content of compounds that are beneficial

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to health than the fresh ones (Abushita et al., 2000; Takeoka et al., 2001). Thus, food processing evaluation is important and necessary, and the process as a whole must preserve the activity, quantity, and quality of these compounds.

Given the above information, the objective of this study was to evaluate a new step in the production process of dry tomatoes, i.e., the pre-freezing of the Italian tomatoes and Sweet Grape mini-tomatoes that were pre-dehydrated in an osmotic solution and dehydrated in an adiabatic forced air dryer, by means of analyses of chemical composition, mineral contents, and antioxidants of the fruits *in natura* and of the dehydrated products, aiming at developing a product with a new variety, not used industrially (Sweet Grape), and the maintenance of the nutritional characteristics of the products.

2 MATERIALS AND METHODS

The samples of *in natura* Italian tomatoes were obtained from the local market in the city of Piracicaba, SP. The *in natura* Sweet Grape mini-tomatoes were obtained from the company Sakata in the producing region of the interior of the São Paulo state. Dehydration of the Italian and Sweet Grape tomatoes was performed in the pilot plant of the Department of Agrobusiness, Food and Nutrition (LAN) of the "Luiz de Queiroz" College of Agriculture (ESALQ), Piracicaba (SP, Brazil).

For the processing, the *in natura* fruits were selected, hygienized, and sanitized with sodium hypochlorite and then frozen at -22°C to preserve the feedstock and facilitate the following steps. In the case of Sweet Grape, as it would be dehydrated whole, freezing was important to break the skin and facilitate the subsequent dehydration; the Italian tomatoes were cut into four parts. Finally, at the end of the processing, the dehydrated tomatoes were stored in aluminum packages, coated with polyethylene (dimensions: 215 × 175 mm; capacity: 500 g), and frozen at -22°C for 10 days, waiting for the analyses, in order to preserve the nutrients and feedstock.

2.1 Dehydration

According to Correia et al. (2015), the first step of the processing involved the osmotic dehydration in an osmotic solution of sodium chloride (400 g) and inverted sugar (31.6 kg) at a concentration of 75° Brix, with a proportion of tomato and solution 1:4 for a period of 40 min at 25°C. The tomatoes were drained in sieves, placed in perforated trays, and, later transferred to the adiabatic convective dryer with air circulation (MARCONI – MA035/3BXI/TOM). This part of the processing was performed in two steps: 80°C for 2 h and then the temperature was reduced to 70°C, which remained for 11 h. The above specific conditions were determined in previous studies for process optimization by Correia et al. (2015).

For chemical and mineral composition analyses, samples of *in natura* Italian tomato, dehydrated Italian, *in natura* Sweet Grape mini-tomato, and dehydrated Sweet Grape were used. The samples were dried in an oven at 50°C for 2 days, ground separately in a blender, homogenized, and stored frozen at -22°C. The chemical composition performed in the samples involved moisture content, ashes, ether extract (lipids), proteins, dietary fiber (soluble and insoluble), and carbohydrates. The mineral composition analysis performed presented 13 macro- and micro-minerals (nitrogen, phosphorous, potassium, calcium, magnesium, sulfur, iron, manganese, copper, zinc, sodium, boron, and aluminum).

For the antioxidant analyses (total phenolic compounds, lutein, beta-carotene, lycopene, and ascorbic acid), fruit samples of the *in natura* Italian and Sweet Grape, as well as samples of the dehydrated products (Italian and Sweet Grape tomatoes) were used.

2.2 Chemical composition

For moisture content determination, the gravimetric method was used to determine the mass loss of the dried and ground sample that was heated in triplicate at 105°C until constant mass, according to the method from the Association of Official Analytical Chemists (AOAC, 2006). The ashes were determined using the muffle furnace regulated at 550°C for a period of 48 h (AOAC, 2006). The lipid determination was performed with solvent hexane in the equipment Soxhlet for 8 h, following the method Bc 3-49 of the American Oil Chemists Society (AOCS, 2003). The crude protein was quantified by the method of Kjeldal (micro) for determining the nitrogen of the dry sample, with a nitrogen/protein conversion factor value of 6.25 (AOAC, 2005). The presence of fibers was determined by the gravimetric-enzymatic method according to Asp et al. (1983), which quantifies the dietary fiber by the sum of the soluble and insoluble fiber determined in the methodology. Carbohydrate quantification was executed by the following difference calculation (Equation 1), which considers the other components determined:

$$\%Carbohydrates = 100 - (\%Ashes + \%Ether\ Extract + \%Proteins + \%Fibers) \quad (1)$$

The analyses were performed in triplicate from the dry and ground material. The results were expressed in percentage or grams per 100 grams of the product (g 100 g^{-1}) on the dry basis.

2.3 Mineral composition

The macro- and micronutrients, such as phosphorous, potassium, calcium, magnesium, sulfur, iron, manganese, copper, zinc, sodium, and aluminum, were determined by the methodology based on AOAC International (AOAC, 2005) using nitro-perchloric digestion, and the absorbance reading in an atomic absorption spectrophotometer (PERKIN ELMER, model 3110, Norwalk, CT, EUA) was performed. For nitrogen determination, sulfuric acid digestion was used. For boron determination, dry digestion in a muffle was used. The results were expressed in milligrams per 100 grams of product (mg 100 g^{-1}) on the dry basis.

2.4 Antioxidant compounds

2.4.1 Phenolic compounds

The determination of the total phenolic compounds was performed according to Genovese et al. (2003). The gallic acid

was used as the standard, and the results were expressed in milligrams of gallic acid equivalent to 100 grams of the product (mg GAE 100 g^{-1}) on the dry basis.

2.4.2 Carotenoids: lutein, beta-carotene, and lycopene

This analysis used the equipment of high-performance liquid chromatography (HPLC) (SHIMADZU, LC Prominence 20A, Japan) with diode array detector (SHIMADZU, SPD-M20A) and C30 carotenoid column (YMC, YMC C30 Carotenoid, 5.0 μm × 250 mm × 4.6 mm). Carotenoid extraction was performed according to Rodriguez-Amaya (2001). For extraction, 0.5 g of frozen and homogenized sample *in natura* fruit and the dehydrated product was weighed, transferred to porcelain gravel, and added with celite (10 g). The solvent used for extracting the carotenoids was acetone cooled by a volume of 40 mL. The maceration was then carried out, and the obtained mixture was then vacuum filtered on a slurry of the plate and synthesized into a 500 mL kitassate. The ketone extract of the kitassate was transferred to the separatory funnel containing approximately 15 mL of petroleum ether. For the complete removal of acetone and transfer of the carotenoids to the petroleum ether, the extract was washed twice with 250 mL of distilled water. After washing, the petroleum ether extract (upper phase) and water (low phase) of the separation funnel were separated.

The extract was funnel filtered with glass wool and anhydrous sodium sulfate, and the filtrate was collected in a 25 mL Amber tube. Then, the solvent was removed under nitrogen flow until drying. For HPLC injection, the contents were resolubilized with methanol/dichloromethane (2 mL) and tert-butyl methyl ether (TBME) (2 mL) with chromatographic purity. Then, a 1.0 mL aliquot was filtered with a 0.2 μm and 13 mm filter syringe for a vial suitable for HPLC injection and packaged in the order of injection. The mobile phase was composed of dichloromethane, TBME, acetonitrile, and water under continuous flow. The injection volume used was 20 μl. The results were expressed in micrograms per gram of product (μg g^{-1}) on the dry basis, and the data were analyzed using the Labsolutions software.

2.4.3 Ascorbic acid: vitamin C

The ascorbic acid was determined by the titrimetric method of Tillmans modified by Benassi and Antunes (1988), which is based on the reduction of the 2,6-dichlorophenol-indophenol-sodium by the ascorbic acid. The results were expressed in milligrams of ascorbic acid per 100 grams of sample (mg 100 g^{-1}) on the dry basis.

2.5 Statistical analysis

This experiment used a completely randomized design. A Tukey's test with $\alpha \geq 0.05$ was performed to determine statistically significant differences between the samples. The analyses were realized in triplicate. The mean and standard deviation for each sample or treatment were calculated.

3 RESULTS AND DISCUSSION

3.1 Chemical composition

The results for the chemical composition of moisture content, ashes, lipids, proteins, fibers, and carbohydrates are presented in Table 1.

Analyzing the moisture content results, it is observed that the tomatoes *in natura*, both Sweet Grape and Italian, presented close moisture values, 93.37% for the Italian tomatoes and 92.03% for the Sweet Grape tomatoes, without statistical difference between the results. Both dehydrated products studied had an average of 49.57 and 44.89% for the dehydrated Italian and Sweet Grape tomatoes, respectively; these two values were statistically different from each other. Therefore, the dehydrated Sweet Grape tomatoes achieved a significantly lower moisture than the other product, with this difference in moisture due to, mainly, form, size, and geometry of the fruit that eventually influence dehydration time; as bigger fruits take more time to reach the desired 40–50% moisture content, and in the bigger fruits (Italian), the need for cutting into four pieces was observed, so that they would stay in adiabatic dehydration for an equal time. Consequently, these factors resulted in different moisture losses and showed that Sweet Grape, due to its reduced size, was more efficient in terms of water removal. Abreu et al. (2011) evaluated dehydrated tomato products and observed moisture averages between 39.2 and 66.6%. From the obtained results, it can be noted that the *in natura* tomatoes reached higher moisture content, whereas the dehydrated products reached low humidities as expected and close to each other, which ensures a higher lifespan of the products.

In the analysis of ashes, the results obtained for the *in natura* Italian and Sweet Grape tomatoes was 9.43 and 6.45 g 100 g^{-1}, respectively, with statistical differences between the *in natura*

Table 1. Centesimal composition of the Italian and Sweet Grape tomatoes, dehydrated and *in natura* (% or g 100 g^{-1} on the dry basis, average values, ± SD $n = 3$)*.

	Italian tomatoes	Dehydrated Italian tomatoes	Sweet Grape tomatoes	Dehydrated Sweet Grape tomatoes
Humidity	93.37 ± 0.17 a	49.57 ± 0.18 b	92.03 ± 0.35 a	44.89 ± 1.82 c
Ashes	9.43 ± 0.04 a	4.18 ± 0.65 d	6.45 ± 0.22 b	5.26 ± 0.23 c
Ether extract	3.09 ± 0.05 ab	1.01 ± 0.27 c	4.70 ± 0.70 a	2.78 ± 1.02 b
Proteins	4.24 ± 0.09 a	1.70 ± 0.17 b	2.20 ± 0.27 b	1.97 ± 0.64 b
Dietary fiber	31.49 ± 0.84 a	9.91 ± 0.31 c	22.51 ± 1.11 b	9.81 ± 1.02 c
Carbohydrates	51.76 ± 0.89 c	83.19 ± 1.35 a	64.14 ± 1.64 b	80.18 ± 2.20 a

*Different letters in the horizontal lines differ significantly ($p \leq 0.05$); Average of the triplicate ± SD; SD: standard deviation.

tomato varieties. The results for the dehydrated products were 4.18 and 5.26 g 100 g^{-1} for the dehydrated Italian and Sweet Grape tomatoes, respectively, with a significant statistical difference between the two dehydrated products and both differed from the *in natura* fruit. The differences noted are explained by the growth conditions (climate, soil, and fertilization) and the processing method. In the ether extract analysis, the following results were obtained for the *in natura* tomatoes: 3.09 g 100 g^{-1} for Italian and 4.70 g 100 g^{-1} for Sweet Grape, without statistical differences between them. For the dehydrated products, the results were 1.01 g 100 g^{-1} for the Italian tomatoes and 2.78 g 100 g^{-1} for the Sweet Grape tomatoes. The results showed that both dehydrated products differed statistically from each other. This is due to processing and the characteristics of the varieties such as size and shape.

In the analysis of proteins, the *in natura* Italian and Sweet Grape tomatoes showed protein contents of 4.24 and 2.20 g 100 g^{-1}, respectively, with a significant statistical difference. On the contrary, the results of the dehydrated products were 1.70 and 1.97 g 100 g^{-1} for the Italian and Sweet Grape tomatoes, respectively; therefore, the statistical values obtained for these dehydrated products did not differ significantly from each other. Again, processing had an influence over the differences in the results, as well as the growth conditions and the characteristics of the varieties of shape, size, and weight. In the analysis of fibers, the results for *in natura* Italian and Sweet Grape tomatoes were 31.49 and 22.51 g 100 g^{-1}, respectively, statistically differing from each other. The results of the dehydrated products were 9.91 and 9.81 g 100 g^{-1} for the Italian and Sweet Grape tomatoes, respectively, not differing statistically from each other and from the *in natura* tomatoes. By these values, it is observed that processing was the main factor of difference in the results.

The results of carbohydrates in the *in natura* tomatoes were 51.76 and 64.14 g 100 g^{-1} for the Italian and Sweet Grape tomatoes, respectively, and were significantly different from each other. Regarding processing, the results were 83.19 and 80.18 g 100 g^{-1} for the dehydrated Italian and Sweet grape tomatoes, both without a significant difference. It can be observed that this class of nutrients was concentrated in both dehydrated products with concomitant reduction of fibers.

3.2 Mineral composition

The mineral composition results of the Italian tomatoes and the Sweet Grape mini-tomatoes, in both *in natura* and dehydrated forms, are presented in Table 2.

According to the results, the main minerals present in the tomato were nitrogen, potassium, and phosphorous, followed by sulfur, calcium, and magnesium.

For mineral nitrogen, the results obtained were 2,471.84 and 986.98 mg 100 g^{-1} for *in natura* Italian and dehydrated Italian tomatoes, respectively, 956.62 and 1,188.68 mg 100 g^{-1} for *in natura* Sweet Grape and dehydrated Sweet Grape tomatoes, respectively. For this nutrient, there was a difference between the tomato varieties, due to the growing conditions (soil, fertilization, and climate). Thermal processing for the Sweet Grape tomatoes concentrated this mineral's content and for the Italian tomatoes reduced it significantly, with differences between the dehydrated products. These results are explained by the processing.

The results of the main minerals, such as phosphorous, potassium, calcium, magnesium, and zinc, demonstrated that processing promoted their decrease in both varieties studied, and only in calcium this decrease was not significant for the Sweet Grape tomatoes. The contents of these minerals in the Italian tomatoes were 456.95, 3814.22, 183.29, 1.45, and 3.46 mg 100 g^{-1}, respectively, and for the dehydrated Italian tomatoes, the results were 234.78, 1,592.26, 80.88, 0.57, and 1.22 mg 100 g^{-1}, respectively. In the *in natura* Sweet Grape tomatoes, these minerals were found in the amounts 330.16, 2354.17, 92.34, 1.43, and 2.94 mg 100 g^{-1}, respectively; and in the dehydrated Sweet Grape tomatoes, the results were 267.25, 1822.67, 90.17, 0.81, and 1.37 mg 100 g^{-1}, respectively. Analyzing the results obtained and the studies, it is observed that the parameters related to fruit production, as well as genetic factors and soil and fertilization conditions, alter these

Table 2. Mineral composition of the dehydrated and in natura Italian and Sweet Grape tomatoes (mg 100 g^{-1} on the dry basis, average values, ± SD, $n = 3$)*.

	Italian tomatoes	Dry Italian tomatoes	Sweet Grape tomatoes	Dry Sweet Grape tomatoes
Nitrogen	2,471.84 ± 36.64 a	986.98 ± 17.79 c	956.62 ± 66.08 d	1,188.68 ± 21.71 b
Phosphorous	456.95 ± 6.90 a	234.78 ± 5.63 d	330.16 ± 1.23 b	267.25 ± 4.06 c
Potassium	3,814.22 ± 47.28 a	1,592.26 ± 27.92 d	2,354.17 ± 67.74 b	1,822.67 ± 45.26 c
Calcium	183.29 ± 5.83 a	80.88 ± 2.04 c	92.34 ± 1.34 b	90.17 ± 1.57 b
Magnesium	1.45 ± 0.02 a	0.57 ± 0.01 c	1.43 ± 0.00 a	0.81 ± 0.01 b
Sulfur	2.09 ± 0.04 a	0.89 ± 0.01 c	1.37 ± 0.01 b	0.89 ± 0.01 c
Iron	0.05 ± 0.00 b	0.05 ± 0.00 b	0.06 ± 0.00 a	0.04 ± 0.00 c
Manganese	1.31 ± 0.03 b	0.49 ± 0.01 d	2.26 ± 0.02 a	0.59 ± 0.03 c
Copper	0.87 ± 0.01 a	0.34 ± 0.01 c	0.58 ± 0.01 b	0.32 ± 0.00 c
Zinc	3.46 ± 0.05 a	1.22 ± 0.02 d	2.94 ± 0.04 b	1.37 ± 0.01 c
Sodium	20.70 ± 0.26 c	419.30 ± 9.54 b	25.00 ± 0.24 c	525.19 ± 8.75 a
Boron	1.29 ± 1.30 c	0.98 ± 0.03 d	2.36 ± 0.12 a	1.92 ± 0.01 b
Aluminum	2.31 ± 0.05 ab	2.64 ± 0.08 a	1.78 ± 0.08 c	1.94 ± 0.35 bc

*Averages with different letters in the horizontal lines differ significantly from each other ($p \leq 0.05$); Average of the triplicate ± SD; SD: standard deviation.

minerals' content, causing tomato varieties to have different quantities of these minerals. Thermal processing decreases these minerals, as the use of dehydration techniques for moisture content reduction and water activity results in the elimination of water by the product carrying some mineral salts with it. The results are in agreement with the studies presented and follow a decreasing trend; however, for the Sweet Grape tomatoes, the reduction was smaller.

The results of iron content were 0.05, 0.05, 0.06, and 0.04 mg 100 g^{-1} for *in natura* Italian, dehydrated Italian, *in natura* Sweet Grape, and dehydrated Sweet grape tomatoes, respectively. It can be observed that iron content decreased throughout processing in Sweet Grape, whereas there was no difference for the other varieties studied.

The results on sodium content were 20.70, 419.30, 25.00, and 525.19 mg 100 g^{-1} for *in natura* Italian, dehydrated Italian, *in natura* Sweet Grape, and dehydrated Sweet Grape tomatoes, respectively. Both *in natura* tomatoes did not differ from each other; however, the dehydrated products had different values from each other and from the *in natura* fruits. These results are explained by the fact that the two dehydrated products had salt (sodium chloride) added during processing and, therefore, presented sodium contents expressively higher than the *in natura* tomatoes. The processing performed in the Sweet Grape tomatoes significantly increased the sodium content, more than that performed in the Italian tomatoes.

Concerning the other minerals analyzed, it was observed that for sulfur, manganese, copper, and boron, the results of the processed dry products were lower compared with the *in natura* fruits. It is also possible to conclude that processing, when performed in the Sweet Grape tomatoes, presented better results, which means lower mineral decreases, except for sulfur and copper, for which both products did not differ from each other. In relation to the mineral aluminum, there was a difference between the varieties and between the products; the processing concentrated the contents of this mineral for both varieties, with the highest result observed in the Italian tomatoes.

3.3 Antioxidant composition

In this study, a concentration of phenolic compounds and a reduction of carotenoids were observed. With processing, there was a significant reduction in lutein and beta-carotene in both varieties. For the carotenoid lycopene, the observed reduction was not significant for the varieties. Regarding ascorbic acid, there was a significant reduction in both varieties. The results are expressed in Table 3.

The results for the phenolic class of antioxidants in the *in natura* tomatoes were 82.45 and 106.58 mg GAE 100 g^{-1} for the Italian and Sweet Grape tomatoes, respectively. In relation to the dehydrated products, the results were 202.92 and 335.14 mg GAE 100 g^{-1} for the dehydrated Italian tomatoes and Sweet Grape mini-tomatoes, respectively. In their study, Chang et al. (2006) concluded that, after processing, the total phenolic content increases 13–29% in hot air-dehydrated products. The use of higher temperatures in dehydration, besides reducing water activity, which concentrates the compounds present in the feedstock, inactivated enzymes that degrade the phenolics, and released this class of compounds from the matrix by means of breaking of the cellular constituents.

It was observed that processing reduced the contents of the carotenoids analyzed. The lutein results demonstrate that the samples of *in natura* tomatoes had significant differences from each other, with the Italian tomatoes presenting the superior content (2.81 and 2.06 $\mu g\ g^{-1}$, respectively). Regarding the processing, for both varieties, lutein content was reduced (1.70 and 1.16 $\mu g\ g^{-1}$, respectively); nonetheless, the two processed products did not differ from each other. It can be deduced that processing caused a significant lutein loss, with the Sweet Grape tomatoes presenting the highest lutein loss (43.70%), which allows the affirmation that the process, when performed in the Italian tomatoes, reduces less of the referred nutrient (39.50%).

The second most important carotenoid in tomatoes, the beta-carotene, was detected and quantified, and the results demonstrated that the Italian and Sweet Grape *in natura* tomato samples did not present a significant difference from each other, with the Italian tomatoes presenting the superior content (8.40 and 8.01 $\mu g\ g^{-1}$, respectively). Regarding the processing, for both varieties, beta-carotene content was reduced (4.10 and 6.04 $\mu g\ g^{-1}$, respectively) and the products differed from each other, with the Sweet Grape tomatoes presenting the highest content, or being the one which presented the least decrease. Based on the results, it is possible to say that processing led to a significant loss of beta-carotene, with the highest beta-carotene loss (51.20%) detected in the Italian tomatoes, which allows the affirmation that the process, when performed in the Sweet Grape tomatoes, reduces less of the referred compound (24.60%).

The results for the main carotenoid analyzed in tomatoes, lycopene, demonstrated that the Italian and Sweet Grape *in natura*

Table 3. Results of the antioxidant compounds on the dry basis: total phenolics (mg GAE 100 mg^{-1}); lutein, beta-carotene, and lycopene ($\mu g\ g^{-1}$); and ascorbic acid (mg 100 g^{-1}) (average values, ± SD, $n = 3$)*.

	Italian tomatoes	Dehydrated Italian tomatoes	Sweet Grape tomatoes	Dehydrated Sweet Grape tomatoes
Total phenolics	82.45 ± 4.23 d	202.92 ± 2.78 b	106.58 ± 2.15 c	335.14 ± 6.65 a
Lutein	2.81 ± 0.40 a	1.70 ± 0.15 bc	2.06 ± 0.33 b	1.16 ± 0.10 c
Beta-carotene	8.40 ± 0.15 a	4.10 ± 0.09 c	8.01 ± 0.62 a	6.04 ± 0.34 b
Lycopene	15.04 ± 0.47 a	13.00 ± 2.94 ab	9.75 ± 0.44 bc	8.91 ± 0.66 c
Ascorbic acid	12.08 ± 0.72 ab	7.08 ± 0.72 c	14.58 ± 1.80 a	10.42 ± 1.80 bc

*Different letters in the horizontal lines differ significantly ($p \leq 0.05$); Average of the triplicate ± SD; SD: standard deviation.

tomato samples had significant differences between them, with the Italian being the one with the highest amount (15.04 and 9.75 $\mu g\ g^{-1}$, respectively). Regarding the processing, for both varieties, lycopene content was reduced (13.00 and 8.91 $\mu g\ g^{-1}$, respectively). A tomato product with 10% final moisture content had its lycopene amount decreased by 10% after drying at 110°C for 4 h, and it was not altered during drying at 80°C for 7 h (Giovanelli et al., 2002; Lavelli et al., 1999; Zanoni et al., 1999). Similar to the other carotenoids, it is noted that lycopene content was reduced by processing; nevertheless, for both varieties, this was not a significant decrease, with 15.60% for the Italian tomatoes and 8.60% for the Sweet Grape tomatoes, which means that the process, when applied to the Sweet Grape tomatoes, reduces less of the lycopene (8.60%), owing mainly to the process conditions and carotenoid pigment stability in the matrix.

For the ascorbic acid, the results were 12.08 and 14.58 mg 100 g^{-1} for the *in natura* Italian and Sweet Grape tomatoes, respectively. Concerning the dehydrated products, the results were 7.08 and 10.42 mg 100 g^{-1} for the Italian and Sweet Grape tomatoes, respectively. The two dehydrated products were observed to have statistically equal values. Processing generated losses in the ascorbic acid content of 41.40% in the Italian tomatoes and 28.54% in the Sweet Grape tomatoes. Chang et al. (2006) studied the effect of hot air drying and noted that the *in natura* tomatoes presented higher amounts compared with processed ones; there was a 56–61% reduction. Ascorbic acid demonstrated thermosensitivity, which justifies its decreases with processing.

4 CONCLUSION

The nutritional quality of the end product is confirmed, due to the maintenance of the compounds of interest (antioxidants) and their elevated percentage of retention at the end of the processing, mainly of the carotenoids lycopene and beta-carotene. Regarding phenolic compounds, there was an expressive post-processing increase. The ascorbic acid content presented a significant retention, which is very similar to the carotenoid lutein. The elevated retention percentages observed in this study of at least 49–50% are desirable in the end product, in view of the nutritional quality.

The product of the Sweet Grape mini-tomatoes made from osmotic dehydration followed by adiabatic drying in a forced air circulation oven reduced less of the nutrients in comparison with the other varieties studied; therefore, both the variety Sweet Grape and the proposed processing can be used in the industry of tomato processing as an alternative of new products, with different characteristics from those offered by the products that are nowadays available in markets.

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